

## CLAIMS

We claim:

1. A method of estimating end-to-end path capacity in a network, comprising:  
probing an end-to-end path to identify addresses of all hops on the end-to-end path;  
generating at least one time-stamp request packet;  
transmitting the at least one time-stamp request packet to at least one hop on the end-to-end path;  
generating a time-stamp in response to the time-stamp request packet with the hop; and  
processing the time-stamp to produce at least one QoS estimate.
2. The method of claim 1, wherein probing on the end-to-end path comprises using a Traceroute application to identify hops on the end-to-end path.
3. The method of claim 1, wherein probing the end-to-end path occurs from one selected from a group consisting of a source node, a destination node, and both a source node and a destination node.
4. The method of claim 1, wherein processing the time-stamp is performed at one selected from a group consisting of a source node, a destination node, and both a source and destination node.

5. The method of claim 1, wherein the time-stamp request packets are ICMP requests.
6. The method of claim 1, wherein the number of generated and processed time-stamp request packets is at least five.
7. The method of claim 1, further comprising generating pairs of time-stamp request packets more often to specific hops on the end-to-end path.
8. The method of claim 7, wherein hops subject to more frequent probing are determined based on at least one of: a variation pattern of utilization; a queuing delay, a queue size, a processing delay, an available bandwidth, and a congestion status.
9. The method of claim 1, further comprising generating time-stamp requests less often to specific hops on the end-to-end path.
10. The method of claim 9, wherein hops subject to less frequent probing are determined based on at least one of: a variation pattern of utilization; a queuing delay, a queue size, a processing delay, an available bandwidth, a congestion status.

11. The method of claim 1, further comprising introducing certain latency between consecutive time-stamp request packet transmissions.
12. The method of claim 1, further comprising increasing the time-stamp request packet size by adding dummy data to the time-stamp request packet to increase sensitivity in the case of a fast link.
13. The method of claim 5, further comprising increasing the ICMP request size by adding dummy data in an IP payload field of ICMP request to increase sensitivity in the case of a fast link.
14. The method of claim 1, wherein the QoS estimate comprises a link and path capacity.
15. The method of claim 1, wherein the QoS estimate comprises an estimate of queuing delay at the hop.
16. The method of claim 1, wherein the QoS estimate comprises an estimate of link and path utilization.
17. The method of claim 1, wherein the QoS estimate comprises an estimate of link and path available bandwidth.

18. The method of claim 1, wherein the QoS estimate comprises an estimate of interfering flows at the hop.

19. The method of claim 1, further comprising restarting probing of the end-to-end path in the case of a change in routing tables.

20. An article of manufacture having one or more recordable media storing instructions thereon which, when executed by a system, cause the system to estimate end-to-end path capacity in a network by:

probing an end-to-end path to identify addresses of all hops on the end-to-end path;  
generating at least one time-stamp request packet;  
transmitting said at least one time-stamp request packet to at least one hop on the end-to-end path;  
generating a time-stamp in response to said time-stamp request packet with said hop; and  
processing said time-stamp to produce at least one QoS estimate.

21. A router comprising:  
a queue to store outgoing packets;  
IP processing coupled to the queue to probe an end-to-end path in a network to identify addresses of all hops on the end-to-end path, generate and transmit at least one time-stamp request packet to at least one hop on the end-to-end path, and receive and process a time-stamp in

response to the time-stamp request packet from the at least one hop to produce at least one QoS estimate.

22. A method of estimating end-to-end path capacity in a network, comprising the steps of:

probing an end-to-end path to identify addresses of a plurality of hops on the end-to-end path;

generating at least one time-stamp request packet with an origination node;

sending the time-stamp request packet to at least one respective hop on the end-to-end path with an origination address of the origination node spoofed to that of another hop on the network;

generating at least one time-stamp with the hop; and

processing in at least one hop on the network the at least one time-stamp to produce a QoS estimate.

23. The method of claim 22, wherein probing the end-to-end path comprises using a Traceroute application to identify addresses of the plurality of hops.

24. The method of claim 22, wherein the origination address is that of a source node on the end-to-end path.

25. The method of claim 22, wherein the origination address is that of a destination node on the end-to-end path.

26. The method of claim 22, wherein probing the end-to-end path is generated from a source node.

27. The method of claim 22, wherein probing the end-to-end path is generated from a destination node.

28. The method of claim 22, wherein probing the end-to-end path is generated from a source node and a destination node.

29. The method of claim 22, wherein the QoS estimate comprises an estimate of link and path capacity.

30. The method of claim 22, wherein the QoS estimate comprises an estimate of queuing delay at the hop.

31. The method of claim 22, wherein the QoS estimate comprises an estimate of link and path utilization.

32. The method of claim 22, wherein the QoS estimate comprises an estimate of link and path available bandwidth.

33. The method of claim 22, wherein the QoS estimate comprises an estimate of interfering flows at the hop.

34. The method of claim 22, further comprising refining the QoS estimate by taking into consideration a propagation delay.

35. An article of manufacture having one or more recordable media storing instructions thereon which, when executed by a system, cause the system to estimate end-to-end path capacity in a network by:

probing an end-to-end path to identify addresses of a plurality of hops on the end-to-end path;

generating at least one time-stamp request packet with an origination node;

sending said time-stamp request packet to at least one respective hop on the end-to-end path with an origination address of said origination node spoofed to that of another hop on said network;

generating at least one time-stamp with said hop; and

processing in at least one hop on said network said at least one time-stamp to produce a QoS estimate.

36. A router comprising:

a queue to store outgoing packets;

IP processing coupled to the queue to receive at least one time-stamp request packet with an origination node to at least one respective hop on the end-to-end path with an origination address of the origination node spoofed to that of another hop on the network, to generate at least one time-stamp, and to process the at least one time-stamp to produce a QoS estimate.

37. A method of estimating end-to-end path QoS in a network, comprising:

probing an end-to-end path to identify a plurality of hops with a node;

generating at least one time-stamp request packet with the node;

transmitting the at least one time-stamp request packet to at least one hop;

generating a time-stamp with the hop;

transmitting the time-stamp to the node; and

processing the at least one time-stamp to produce a QoS estimate.

38. The method of claim 37, wherein the node may be selected from a group of nodes including a source node, a destination node or an independent node.

39. The method of claim 37, wherein the QoS estimate comprises a link and path capacity.



40. The method of claim 37, wherein the QoS estimate comprises an estimate of queuing delay at the hop.

41. The method of claim 37, wherein the QoS estimate comprises an estimate of link and path utilization.

42. The method of claim 37, wherein the QoS estimate comprises an estimate of link and path available bandwidth.

43. The method of claim 37, wherein the QoS estimate comprises an estimate of interfering flows at the hop.

44. An article of manufacture having one or more recordable media storing instructions thereon which, when executed by a system, cause the system to estimate end-to-end path capacity in a network by:

- probing an end-to-end path to identify a plurality of hops with a node;
- generating at least one time-stamp request packet with said node;
- transmitting said at least one time-stamp request packet to at least one hop;
- generating a time-stamp with said hop;
- transmitting said time-stamp to said node; and
- processing said at least one time-stamp to produce a QoS estimate.

45. A method comprising:

obtaining a current total raw capacity of a wireless link;

estimating packet congestion;

determining an amount of available raw link capacity; and

calculating a QoS value based on the amount of available raw link capacity.

46. The method defined in Claim 45 further comprising determining a queuing delay for a first packet to reach a remote terminal.

47. The method defined in Claim 46 wherein determining the queuing delay is based on a total number of transmissions for a second packet ahead of the first packet in a congestion queue of an access router, a contention time for one or more retransmissions of the second packet, a timeout delay before a decision as to retransmission, a transmission delay for the first packet over the wireless link, a propagation delay of the first packet over the wireless link, and the time spent by the second packet before reaching the head of a contention queue.

48. The method defined in Claim 46 wherein determining the queuing delay is based on, at least in part, a total number of transmissions for a second packet ahead of the first packet in a congestion queue of an access router, and the total number of transmissions is based on a number of frames transmitted successfully, a number of frames retransmitted, a number of frames that exceed a maximum number of retries, and the average contention time.

49. The method defined in Claim 46 wherein determining the queuing delay is based on, at least in part, a total number of transmissions for a second packet ahead of the first packet in a congestion queue of an access router, and the total number of transmissions is based on the probability of packet loss on the wireless link.

50. The method defined in Claim 49 further comprising:  
measuring an average packet loss value for a wired portion of a network; and  
calculating a packet loss value for a wireless link in an end-to-end network path as a function of the packet loss value for the wired portion of the network.

51. The method defined in Claim 49 further comprising:  
transmitting a ping request to a hop on the path;  
receiving a ping reply; and  
processing the ping reply to generate the quality of service (QoS) estimate.

52. A router comprising:  
a queue to store outgoing packets;  
IP processing coupled to the queue to obtain a current total raw capacity of a wireless link, estimate packet congestion, determine an amount of available raw link capacity, and  
calculate a QoS value based on the amount of available raw link capacity.

53. The router defined in Claim 52 wherein the IP processing determines a queuing delay for a first packet to reach a remote terminal.

54. The method defined in Claim 52 wherein the IP processing measures an average packet loss value for a wired portion of a network, and calculates a packet loss value for a wireless link in an end-to-end network path as a function of the packet loss value for the wired portion of the network.

55. The method defined in Claim 52 wherein the IP processing transmits a ping request to a hop on the path, receives a ping reply, and processes the ping reply to generate a quality of service (QoS) estimate.

56. An article of manufacture having one or more recordable media storing instructions thereon which, when executed by a system, cause the system to:

- obtain a current total raw capacity of a wireless link;
- estimate packet congestion;
- determine an amount of available raw link capacity; and
- calculate a QoS value based on the amount of available raw link capacity.

57. A method comprising:

- probing an end-to-end path to identify capacity of routers on the end-to-end path;
- transmitting a ping request to a hop on the path;

receiving a ping reply; and

processing the ping reply to generate a quality of service (QoS) estimate.

58. The method defined in Claim 57 wherein the hop comprises a hop on an IEEE 802.11 wireless local area network (LAN).

59. An article of manufacture having one or more recordable media storing instructions thereon which, when executed by a system, cause the system to:

probe an end-to-end path to identify capacity of routers on the end-to-end path;

transmit a ping request to a hop on the path;

receive a ping reply; and

process the ping reply to generate a quality of service (QoS) estimate.

60. A method comprising:

measuring an average packet loss value for a wired portion of a network; and

calculating a packet loss value for a wireless link in an end-to-end network path as a function of the packet loss value for the wired portion of the network; and

calculating a QoS value based on the packet loss value.

61. An article of manufacture having one or more recordable media storing instructions thereon which, when executed by a system, cause the system to:

measure an average packet loss value for a wired portion of a network; and

calculate a packet loss value for a wireless link in an end-to-end network path as a function of the packet loss value for the wired portion of the network; and  
calculate a QoS value based on the packet loss value.

62. A method of estimating a QoS value for an end-to-end path in a network, comprising the steps of:  
generating a ping request packet with a first hop on the end-to-end path;  
transmitting the ping request packet to a second hop on the end-to-end path;  
receiving, at the first hop, a ping reply from the second hop in response to the ping request packet; and  
calculating a QoS value as a function of the ping reply.